Abstract

With the ever-increasing demand for faster, smaller and less power consuming electronic devices, the need for further miniaturization of the electronic devices grew very much. In order to make the existing devices smaller, the existing techniques of silicon-based electronics industry started to prove inadequate. Hence, instead of opting for a top-down approach, i.e. making smaller devices from bulk by patterning, the trend recently has shifted to a new approach called the bottom-up approach. In this new approach, the small molecules are used as the building blocks to build more complex devices. This opens the path for a whole new branch of electronics, called molecular electronics. Molecular electronics is superior to the conventional silicon-based electronics in terms of ease of fabrication, flexibility, and cost of fabrication – the factors which are vital for the industry. The potential for molecular electronics is immense. Organic light emitting diodes (OLEDs), organic field effect transistors (OFETs), solar cells, and switches are a few examples of organic molecular electronic devices. Many of these devices, such as OLEDs are at par with their inorganic counterparts in terms of performance. However, some of them are yet to be commercialized because of the prevalent difficulty in understanding of their operating mechanisms. Organic molecular memory devices are one such set of devices which fall in this category. Several switching mechanisms have been the main focus in a large number of recent studies on organic molecular memory devices. These mechanisms include metallic filament formation, redox action between a donor and acceptor group, the conformational change of a molecule, incorporation of floating metallic nanoparticles, ferroelectricity etc. The present study explores the possibility of more than one of the above mechanisms in a molecular memory device, and also the ways of tuning the characteristics of the molecular memories by varying the fabrication parameters.

The aim of the thesis is to fabricate and study the switching mechanisms of small molecule-polymer hybrid memories, tune their performance by varying different process parameters such as concentration and rotational speed in the spin coating process. In the beginning, organic molecular memories with a blend of a small molecule 2,3-dichloro-5,6-dicyano-p-benzoquinone (DDQ) and a polymer poly(4-vinyl phenol) (PVP), were fabricated and the switching characteristics of the same were explored. Memories were fabricated in a metal-insulator-metal (MIM) architecture. The concentration of DDQ with respect to that of PVP was varied in this study and the switching direction and the switching mechanisms were found to be dependent on the concentration of DDQ. The devices were found to show both good retention and repeatability properties with the highest ON-OFF ratio of 10^6. Further, the devices showed filamentary conduction with a switching in the negative bias region in the lower DDQ concentrations and a conformational change with switching in positive bias region when the concentration of DDQ was high. In the same order, the next aim of the thesis is to tune the performance metrics of a set of the memory device with the same polymer-small molecule blend, by varying another process parameter of fabrication. Organic molecular MIM memories with a blend of DDQ and PVP were fabricated by spin coating method with different rotational speeds. It was found that the speeds of spin coating dictated the surface morphology of the thin films as the speed of drying the thin films affects the phase segregation. This leads to bigger pits and island-like structures in the surface morphology of the devices fabricated at lower speeds and pinholes at the higher speeds. Pinholes support the filamentary switching and hence the ON-OFF ratio is highest when the speed of rotation is highest. It was found that the ON-OFF ratio increases exponentially with the increase in the rotational speed of the spin coating process. The retention time and endurance studies of the device with the highest speed of rotation were tested and it was found that the device can be used in both RAM and ROM applications as it shows fairly long retention time and is reliable. The studies carried out in this research will provide a better understanding of the switching mechanism of organic molecular memories with the blend of small molecule and polymer. The tuning of the switching mechanism and performance of the memories will lead the path towards further research in the field of organic molecular memories.